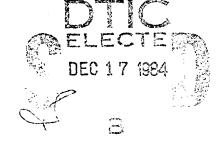AD-A148 616

A Commentary on the Utilization of Real-Time Channel Evaluation Systems in HF Spectrum Management

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Real-Time Channel Evaluation (RTCE) devices are coming into increased use in modern management of HF communications systems. The earliest techniques used in channel evaluation exploited vertical incidence pulse sounders (VIS) and these devices are still being used for some applications. An oblique incidence sounding technology has also been developed employing both pulse and chirp waveform approaches. A variety of RTCE devices are identified in the report but the emphasis is placed on the OIS chirp sounder. Using this device as a canonical channel evaluator, the implications for global, theater, and local HF resource management may be addressed. As one might suspect, there are both advantages and disadvantages which may accrue from construction of a sounder network. Issues include: data applicability, data collection and dissemination, network size and cost, network ECM vulnerabilities, optimum network architecture, and system component reliabilities, to name a few. These issues are outlined in the report.

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A COMMENTARY ON THE UTILIZATION OF REAL-TIME CHANNEL
EVALUATION SYSTEMS IN HF SPECTRUM MANAGEMENT

1.0 INTRODUCTION

Since the discovery of the "Kennelly-Heaviside" layer of ionization in the upper atmosphere, there has developed a synergistic relationship between the ionospheric physicist--who is interested in properties of the geoplasma and the radio engineer--who is concerned with link or broadcast efficiencies and reliabilities. This synergism is most pronounced in the HF portion of the radio spectrum, where a rich and intricate array of ionospheric phenomena "maps" into a complex hierarchy of radiowave effects. This "mapping" is not obviously one-to-one, and this leads to certain difficulties in ionospheric/propagation modelling for the purpose of prediction. Both constituencies (i.e., the radio engineer and the ionosphericist) utilize modelling approaches to satisfy their different but related agendas. The products of research motivated by these agendas have led to global characterizations of the mean ionospheric properties and propagation effects. These characterizations have been quite important in understanding the general vulnerabilities of HF systems under a variety of solar-terrestrial conditions. They certainly have been useful in addressing the intricate problem of world-wide HF spectrum utilization and resource management. Furthermore, refined models have an application in the design of HF systems. In particular, they may be utilized to reduce the "brute force index" of so-called robust systems or the "finesse index" of adaptive systems. Indeed, an ability to reduce the margin design requirements may be achieved through application of modelling approaches, but--owing to ionospheric variability--this capability has not been fully developed even for systems which are vectored for deployment in localized geographical zones which may be associated with a subset of ionospheric climatology. It is felt this "here and now" fine structure resulting from residual ionospheric variabilities cannot be adequately accounted for using global modelling approaches regardless of elegance in approach. The authors are, of course, aware that some theorists will adamantly refute this. The awareness of this problem has led to real-time channel evaluation approaches to characterize the "local" environment more precisely. This approach yields an HF channel "snapshot", and can be of considerable value if analyzed properly and exploited in a timely and efficient manner. How this "snapshot" degrades in time or how it becomes defocussed for regions outside the field of view remain open questions.

2.0 TYPES OF RTCE SYSTEMS

At this point, it is necessary to distinguish between systems which measure the ionospheric properties (as a primary product) and those systems which produce directly applicable HF deliverables within which are imbedded ionospheric

information. Within the former category are included: incoherent scatter radars, Faraday rotation (total electron content) polarimeters, satellite and rocket probes, and the like. Indeed, it may be argued that vertical incidence sounders (VIS) are principally ionospheric monitors. Within the latter category, we include those systems which provide information which is of direct benefit to a specified HF communication system.

According to CCIR, there are three classes of RTCE, and these include the following: [CCIR, 1982]

    1-Remote Transmitted Signal Pre-processing
    2-Base Transmitted Signal Pre-processing
    3-Remote Received Signal Processing

In the first class is included Oblique Incidence Sounding (OIS) and Channel Evaluation and Calling (CHEC). The second class includes Vertical Incidence Sounding (VIS), Radar Backscatter Sounding (RBS), and Frequency Monitoring (FM). The Third class includes Pilot-Tone Sounding (PTS) and Error Counting (EC).

For purposes of this paper, we are principally interested in the attributes of the first class of RTCE with major emphasis directed toward the OIS system. Furthermore, we shall restrict our discussion to the chirpsounder variety of OIS. Nevertheless, the specific remarks may apply equally to all classes and sub-classes of RTCE

The chirpsounder system is currently of interest for application in quasi-real time spectrum management at HF because of a lower transmission power requirement (as compared to pulse OIS). Both the chirp and the pulse OIS systems require synchronization between transmitter and receiver; however, the former system transmits a low frequency sweep (or chirp) rather than a relatively higher power sequence of pulses covering the HF band of interest. An early description of the chirpsounder system is due to Barry and Fenwick [1965]

3.0 THE NRL RTCE STUDY PROGRAM

The Ionospheric Effects Branch (Code 4180) of NRL has been engaged in several experimental efforts directed toward development of an understanding of the degree to which sounder data may be exploited for various C^3I activities within DoD. The earliest efforts examined the efficacy of RTCE to assist in the management of signal intercept resources. In this instance, satellite-borne VIS instruments were considered appropriate RTCE devices for HF channel characterization over denied areas. Subsequently, emphasis changed to the area of HF spectrum management.

Since 1980, a series of short-term experimental "campaigns" were executed by NRL utilizing the AN/TRQ-35, an OIS chirpsounder system being procured by DoD to improve HF communication capabilities. These campaigns were conducted during the moderate to high solar activity epoch between 1980 and the present, included both fixed and mobile platforms, involved high latitude, middle latitude, and equatorial zones, and also incorporated both short and long paths. A number of these results have been published as NRL reports or have been presented at certain topical conferences. For example, see Uffelman et al [1982], Uffelman [1983] and Uffelman and Hoover [1984].

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On the basis of the experimental efforts indicated above, a working hypothesis has been developed:

"Since ionospheric propagation models have strength in terms of global extrapolation in space and time, but are weak in terms of precise specification even over known links; and since RTCE devices (e.g., the AN/TRQ-35) exhibit strength in terms of channel specifications over sampled circuits, but have no intrinsic capability to extrapolate in either space or time: then, the advantages of propagation models and RTCE may be achieved simultaneously through an appropriate combination of the two approaches, such that a precise global HF channel specification and forecasting system may be developed."

Tests of this hypothesis are now being carried out under sponsorship of the US Army. It is noteworthy that the PROPHET architecture, developed by NOSC, includes a model called MINIMUF which is part of the Army PROPHET Evaluation System or APES. This model has been modified to allow for an update using local AN/TRQ-35 input. A brief description of the NRL update procedure has been presented by Uffelman and Hoover [1984] using both IONCAP and MINIMUF.

4.0 DoD CHIRPSOUNDER DEPLOYMENT PLANS

As is well known, the US DoD (and some Allies as well) have developed plans for utilization of the AN/TRQ-35 oblique chirp sounder to assist in HF spectrum management. The US plans were developed by the services somewhat independently and, as a result, the initial plans gave the appearance of being uncoordinated and somewhat duplicative. In order to "get a handle" on service deployment plans and OIS acquisition strategies, the OJCS "encouraged" the development of a "Chirpsounder Directory" under the aegis of the USMCEB. This directory includes the planned or existing location of AN/TRQ-35 transmitters, time-slice information and other vitae. The UK has also developed a similar document, and it is understood that a NATO document is to be prepared. It is the intent to update the directories periodically.

5.0 ADVANTAGES OF CHIRPSOUNDER NETWORKING

There are clear advantages which may accrue from accumulation of HF channel information in quasi-real time over a large area. In the final analysis, this involves a networking approach. As a minimum, we could view selected constellations of AN/TRQ-35 sounders as ingredients in a chirpsounder network. Suppose that there exist N sounder transmitters accessible to a single sounder receiver facility. This situation will yield N independent "control" points (corresponding to N ionospheric reflection points) distributed about the receiver facility. Given another receiver facility, N additional "control" points may be ascertained. If the European theater is used as an example—12 chirpsounder transmitters are now listed in the USMCEB directory—, and if receivers are essentially co-located with transmitters, then there will be 11 x 12 = 132 "control" points distributed over the European theater. However, each "control" point is doubly redundant if path reciprocity is assumed.

There are several ways this information may be used. The obvious procedure is to convert the OIS time delay versus frequency data [i.e., $t'(f)$] corresponding to each "control" point into an effective electron density profile [i.e., $N(h)$]. Procedures for doing this have been developed. This leads to a

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three dimensional picture of the ionospheric electron density over the region of interest, with a spacial resolution defined by the distribution of "control" points. The ionospheric properties between the "control" points might be obtained by exploiting a model extrapolation algorithm or simply through linear interpolation. In any case, it is possible to obtain a continuous respresentation of the ionosphere over the region of interest. This information may be used to deduce routine HF parameters such as estimates of the Maximum Observable Frequencies (MOF). Proceedures for accomplishing this are also well known.

Another possibility for exploiting the data is to deduce the effective input parameters which force a specified model representation of the Maximum Useable Frequency (for example) to be equal to the MOF for each sampled path (and "control" point) in question. In the case of MINIMUF, one generates a pseudo-sunspot number pR such that MUF (from MINIMUF) = MOF (from sounder). Thus one generates a set of pseudo-sunspot numbers for each "control" point in the data base. Owing to ionospheric variability, it is anticipated that the set of pR's will also exhibit spatial variability. As before, we may develop a continuous pR representation over the region of interest by either model extrapolation or simply by linear interpolation. This pR representation may be used directly by MINIMUF for arbitrary paths over the region of interest.

Using either of the two approaches outlined above, it is possible to extract estimates of actual channel properties (such as the MOF). The cornerstone of the process is the timely amalgamation of sounder data. In the former approach a model is not essential. Indeed the "model" is generated by the data. In the latter approach it is central to the process. Nevertheless, in order to extrapolate for considerable distances away from the concentration of "control" points, or to forecast departures from the current representation, a model is necessary. Large temporal or spatial extrapolations ultimately will lead to an equivalence with climatological (mean) model estimates of the requisite parameters. This default condition will occur for temporal extrapolations in excess of T hours and for spatial extrapolations in excess of D kilometers from the closest ionsonde "control" point.

NRL is investigating the temporal and spatial decorrelation of sounder data. The time period for which sounder estimates are valid for even a fixed circuit is typically quite small unless account is taken of local solar zenith angle variations with time. Taking this factor into account--equivalent to model exploitation--we find that sounder extrapolations become more credible. The most significant degradation component arises by virtue of the intrinsic ionospheric variability associated with travelling ionospheric disturbances and large MOF excursions accompanying geomagnetic substorms. The ionospheric variability is clearly region-dependent. The large MUF excursions associated with magnetic storms may, in principle, be estimated by taking other solar-terrstrial observations into account. In short, model improvements should lead to an increase in the correlation time with the ultimate improvement being commensurate with the time lags associated with the solar-terrestrial system itself. In terms of magnetic storm response, this might be the order of several days from the time at which storm-producing solar active regions first appear. This ultimate improvement is not yet realizable. NRL studies, albeit preliminary, have shown that models must be updated more often during magetically active periods. In practice, we find that updated model estimates of the MOF remain within 1 MHz of the actual value for up to 24 hours during benign periods, but the epoch is less than 3 hours for disturbed periods (on an RMS basis). Since the data base is limited, this is not expected to be a general result.

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A major factor in the decision concerning the placement of sounders is the spatial correlation distance. Studies have been carried out by Rush [1976] using the parameter foF2, taking local time differences into account. Other studies have been carried out by Milsom [1983], and more recently Widdicks [1984] has corroborated the general conclusions obtained by Rush. In short, it has been found that the east-west correlation distance for foF2 data (at the 80% level) is about 1000 km, and the north-south correlation distance is of the order of 750 km. Correlation for the MOF's were found to be less. Correlation less than 80% will not lead to a significant improvement in forecasting accuracy, with the consequence that sounder spacing should be restricted to a distance somewhat less than that defined by correlation analyses.

It is felt by the authors of this report that improvement in correlation is least during the midday and post-midnight periods, since the average derivative of the electron density is a minimum at these times. The greatest improvement is obtained during the sunrise and sunset periods, during which east-west station separations are quite important.

A further improvement in correlation may be obtained by transferring sounder-derived values of either foF2 or MOF to the latitude and longitude prescribed for cross-correlation. In this way all correlation would be performed in the same universal time with the local time variations being accommodated implicitly by the transformation. This transformation could be a version of IONCAP, HFMUFES, or even MINIMUF. What is the advantage of this? The major advantage achieved is the incorporation of immediate area-wide perturbations, since the correlation is based upon fixed universal time. Area wide perturbations might include large-scale equatorward-directed TID's and SID effects (in the daytime). It is anticipated that the correlation distances obtained using this approach would be greater than those obtained by cross-correlating ionospheric parameters following a simple local time correction. The north-south correlation would be enhanced the most, provided the transformation model were reasonably good and large scale TID's could be recognized and accounted for.

We maintain that if a network of sounders were to be established, then spatial decorrelation is not a limiting factor for "dense" networks; it becomes an issue only for large extrapolations outside the network coverage zone. Temporal decorrelation is the major problem. However, if the network resources were to remain active (i.e., sounder updates are provided every hour or so as a minimum) then the credibility of the network channel characterization could be maintained.

6.0 CONCLUSION

A sounder network will provide a number of benefits for HF communications, for providing improvements in HF emitter location, and for engaging in propagation tactics. However, it is imperative that validated models be exploited to achieve the optimum regional channel characterization. Spatial decorrelation of the characterization is not felt to be a problem for dense networks. The main problem area is temporal decorrelation. The benefits of networking (coordinating and exchange of chirpsounder data) include frequency pooling and propagation tactics. There are, however, some vulnerabilities associated with establishment of a sounder network. Issues of transmitter identification, transmitter/receiver synchronization, automated ionsonde trace analysis and data dissemination must be fully addressed. In addition, we must also be mindful of enemy spoofing or jamming of network nodes.

As a final note, the authors would like to stress that a total reliance on sounder networks at the expense of appropriate R & D investment in the development of truly robust HF systems would be shortsighted. Sounders, if used properly, can be quite beneficial. However, they should be viewed principally as an interim step in hF improvement. The ultimate step would be the development of a new family of robust radios which are less sensitive to ionospheric eccentricities. At the very least, sounding functions should be engineered into the total system. The system architect should also examine other RTCE schemes in this context as well. After all, there are other issues involved besides the MOF and the LOF.

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